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(54) Filter material

(57) A thermoformable air permeable coherent filter web contains a blend of glass wool fibres with chopped strand glass fibres together with a polymeric binder thermoformable at a temperature from 200-350°F and capable of undergoing cross-linking upon heating to a temperature above 280°F. The web is capable of being embossed in the dry state without cracking or splitting and is useful for making air filters.

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FILTER MATERIAL

This invention relates to a thermoformable air permeable coherent filter web comprising glass fibres and a binder suitable to be embossed and pleated to form an air filter.

Pleated sheet or web glass fibre air filters are desirably employed in a variety of settings because of their high surface-to-volume ratio. For maximum efficiency it is important to maintain adequate spacing between adjacent pleats during use; this spacing is achieved either by a separate spacer or separator element added to the filter, or by providing embossings or deformations such as dimples in the sheet or web itself which serve to maintain space between adjacent folds after pleating.

It has previously been proposed in Mathews et al U.S. Patent No. 3,035,965 to form a paper of glass fibres of less that 2.5 microns diameter coated with a thermoplastic polymer, but the paper lacked chopped strand fibres of larger diameter. Powell et al U.S. Patent No. 4,318,774 describes composite non-woven web of glass fibres and textile fibres with a thermoplastic binder. Klein U.S. Patent No. 4,286,977 describes an air filter comprising small diameter glass fibres, textile fibres and a thermoplastic binder. Buckman U.K. Patent No. 874,383 (1961) describes a pleated air filter having embossed spacers made of synthetic resin impregnated filter paper. Bulletin No. 815E of

Flanders Filter Inc. (1987) also describes a dimpled and pleated air filter. It is believed that it has been the practice to carry out such embossing or deformation during formation of the web or sheet, while it is still in the wet stage of a Fourdrinier machine. Attempts to emboss the sheet or web after drying have not met with success because of the tendency of the web to split or crack, thus destroying its coherency and effectiveness, Since most filter manufacturers or fabricators do not themselves manufacture the filter sheet or web material but nevertheless desire to have a variety of patterns and spacings for the embossing in order to fit the web for the individually designed pleated filter constructions adapted for particular uses, there is a need for a uniform, dry smooth surfaced web or sheet of glass fibre filter material which can be embossed or deformed with simple and inexpensive equipment such as a pair of embossing rolls having the desired pattern.

Thus according to a first aspect of the present invention there is provided a thermoformable filter material, which may be in sheet form, such as an air permeable coherent filter web, which comprises a glass fibre blend consisting essentially of (A) 5-35% by weight of chopped strand fibres having average fibre length of 3-19mm and average fibre diameters of 6-20 micrometers, and (B) the balance glass wool having average fibre lengths of 0.1-5mm and average fibre diameters of 0.2-6 micrometers;
a thermoplastic polymeric binder capable of undergoing cross linking upon heating to a temperature of 280^{o}F or above, the amount of the binder being from 2-30% by

weight of the total glass fibre blend and binder;

the material may preferably have a thickness from 0.012-0.040 inches, a tensile strength (MD) from 4-25 lb/inch width and a tensile strength (CD) from 2-12 lb/inch width, and a basis weight from 40-100 lb/3000 sq.ft.

The Applicants have found that a dry sheet of this (glass fibre) filter material having certain important characteristics can readily be embossed in a dry state without cracking or splitting simply by heating it to a temperature of 200°-350°F and passing it between embossing rolls.

Preferably the material, e.g. a sheet, exhibits an elongation of at least 2.0% upon embossing at 200°F over a boss having a cross section in the form of a segment of a circle having a height of 2mm and a width of 8.5mm. Preferably the material also retains a permanent elongation of at least 1.0% within the embossment after embossing (even when subsequently heated to 280°F or higher) to advance or complete the cross-linking, and cooling to room temperature.

Suitably the material has one or more of the following characteristics:

(a) the glass fibre blend contains 8-15%, such as 9-12%, by weight of chopped strand fibres;

(b) the chopped strand fibres have average lengths of 6-13mm;

(c) the binder composition is present from 3-6%, e.g. 5.3-5.6%, by weight of the total;

(d) the material has a basis weight from 55-75 lb/3000

sq.ft. width;
(e) a Gurley stiffness of at least 1500mg, e.g. 1800mg;
(f) it retains, after embossing at 200°F over a boss having a cross section in the form of a segment of a circle having a height of 2mm and a width of 8.5mm, a permanent elongation of 1-5% even when subsequently heated to 280°F or higher to advance or complete the cross-linking, after cooling to room temperature.

Scoring of the dry material, e.g. web, to facilitate folding to form pleats is preferably carried out on the unheated web before heating and embossing.

Some cross-linking of the binder may occur during the embossing step, depending on the temperature to which the web is heated and the length of time required for embossing; additional cross-linking by further heating after embossing and/or even after collecting the web in pleated form may take place.

The binder is preferably a thermoplastic material such as a vinyl or vinylidene polymer or copolymer which is suitably capable of cross-linking when heated to a temperature of 280°F or above. The cross-linking capability can be provided by incorporating a cross-linking agent capable of reacting with residual vinyl groups or with other reactive moieties such as carboxyl groups in the thermoplastic polymer or copolymer, or by blending with the vinyl or vinylidene polymer or copolymer a second resin or polymeric material capable of undergoing cross-linking when heated such as an aldehyde resin, e.g. a urea-formaldehyde resin,

melamine-formaldehyde resin, phenol-formaldehyde resin, an epoxy resin or the like. For best results it is desirable that the thermoplastic binder material has a glass transition temperature (T_g) of +10°C to +50°C and that it is capable of retaining thermoplasticity when heated to a temperature up to 280°F. Among suitable binders or cross-linkable materials are copolymers of vinyl chloride, vinylidene chloride, vinyl acetate, acrylic esters, acrylonitriles, and the like; the cross-linking capability may be provided by comonomers having pendant carboxyl groups, for example, or by blends with urea-formaldehyde or other thermosetting materials; the cross-linking is suitably activatable by heating to a high temperature of at least 280°F or more.

A second aspect of the present invention relates to a process for the preparation of a thermoformable filter material, the process comprising admixing:

(A) 5 to 35% by weight of chopped strand fibres having average fibre lengths of 3 to 19 mm and average fibre diameters of 6 to 20 micrometers;

(B) the balance of glass wool having average fibre lengths of 0.1 to 5mm and average fibre diameters of 0.2 to 6 micrometers; and

(C) a thermoplastic polymeric binder capable of undergoing cross-linking upon heating to a temperature above 280°F;

this may thereby form a material having a thickness from 0.012 to 0.040 inches, a tensile strength (MD) from 4 to 25 lb/inch width and a tensile strength (CD) from 2 to 12 lb/inch width, and a basis weight from 40 to 100 lb/3000 sq.ft.

The admixing is preferably by wet blending, such as to form a slurry. Suitably the chopped strand fibres and glass wool are first blended to form a glass blend and contacted with an aqueous dispersion of the binder. Preferably this is then dried.

The glass fibre in the material, e.g. web preferably comprises a blend of two types or classes of fibres, one chopped glass fibres and the other glass wool having the preferred dimensions and proportions described. Such fibres are readily obtained from a variety of sources. The blend may be prepared by conventional procedures and equipment. Dry blending can be employed, but it is preferred to employ wet blending in which the fibres are dispersed in an aqueous medium in a beater or pulper or a high shear mixing vat, preferably with the addition of acid to facilitate and assist in the separation of the glass fibres. The binder preferred to provide the necessary coherence and other physical properties to the product may be mixed with the fibre blend during or after preparation of the blend. In a preferred process, the fibre blend is first formed into a web or sheet on a Fourdrinier machine, after which the web or sheet is saturated with an aqueous dispersion of the binder; excess water is then removed by suction on the Fourdrinier and the web or sheet is dried in the usual manner on heated drying cans.

A third aspect of the present invention relates to a process for the preparation of a filter, e.g. an air filter, the process comprising embossing and/or pleating a thermoformable filter material, the material

comprising:

a glass fibre blend comprising (A) 5 to 35% by weight of chopped strand fibres having average fibre lengths of 3 to 19 mm and average fibre diameters of 6 to 20 micrometers, and (B) the balance glass wool having average fibre lengths of 0.1 to 5mm and average fibre diameters of 0.2 to 6 micrometers;

a thermoplastic polymeric binder capable of undergoing cross-linking upon heating to a temperature of above 280°F; the amount of the binder being from 2 to 30% by weight of the total glass fibre blend and binder;

the material preferably has a thickness from 0.012 to 0.040 inches, a tensile strength (MD) from 4 to 25 lb/inch width and a tensile strength (CD) from 2 to 12 lb/inch width, and a basis weight from 40 to 100 lb/3000 sq.ft.

Preferbly this process is preceded by scoring the material to assist pleating. The process preferably additionally comprises embossing the material, such as by heating the material up to 280° to 350°F, e.g. about 300°F, and passed through embossing rolls. The heating is suitably by infra-red radiation. Advantageously the material is then heated to above 280°F to induce cross-linking in the binder.

The present invention in its broadest terms, in a fourth aspect, encompasses a thermoformable filter material comprising a glass fibre blend comprising (A) chopped strand fibres and (B) glass wool, and (C) a thermoplastic polymeric binder having one, some or all of the following characteristics:

1. for the chopped strand fibres:
   (a) they are present at from 5 to 35%, preferably 8 to 15%, by weight;
   (b) they have average fibre lengths of 3 to 19mm;
   (c) they have average fibre diameters of 6 to 20 micrometers;
2. for the glass wool
   (a) this is present as the balance (i.e. the percentage by weight of glass wool and chopped strand fibres total 100%);
   (b) the wool has average fibre lengths of 0.1 to 5mm;
   (c) the wool has average fibre diameters of 0.2 to 6 micrometers;
3. the binder is capable of undergoing cross-linking upon heating to a temperature above 280^{O}F and/or the binder is present at an amount from 2 to 30% by weight of total glass fibre blend and binder;
4. the material has:
   (a) a thickness of from 0.012 to 0.040 inches;
   (b) a tensile strength (MD) from 4 to 25 lb/inch width;
   (c) a tensile strength (CD) from 2 to 12 lb/inch width; and
   (d) a basis weight from 40 to 100 lb/3000 sq.ft.

Preferred features and characteristics of one aspect of the present invention are as for another aspect mutatis mutandis.

The invention will now be described by way of example with reference to the accompanying Example, which is provided for means of illustration and is not to be taken as being limiting on the present invention.

Example 1

A blend of chopped strand glass filament or fiber (diameter 6.5μm) with flame blown glass microfiber or wool (diameter 0.65-2.7μm) was prepared from the following components:

Glass Fiber	Nominal Diameter, μm	Nominal Length, mm
Code 104	0.4	0.2-1
Code 106	0.65	0.5-0.8
Code 110	2.7	0.8-1.2
DE 1/2" 636	6.5	12.5

The code 104, 106 and code 110 are glass microfibers produced by Manville Corp. from a type 475 borosilicate glass. The DE 1/2" 636 is manufactured by Owens-Corning from conventional E glass. Three different blends of the fibers were prepared in the following parts by weight:

Glass Fiber	A	B	C
Code 104	4.4	2.5	8.4
Code 106	70.5	60.6	46.3
Code 110	15.7	17.4	36
DE 1/2" 636	9.4	9.5	11.3

The fibers were blended to form a slurry at a solids level of 5% in water adjusted to pH 2.7 with sulfuric acid. The slurry was formed in a high shear mixing vat. After initial dispersion and blending the slurry was diluted to 2% by weight and metered to the headbox of a Fourdrinier where it was further diluted to a solids content of approximately 0.1-0.5% to assure even fiber distribution. After initial formation of

a fibrous mat on the Fourdrinier screen each of blends A and B was saturated with an aqueous dispersion containing 3-5% by weight of binder. The binder consisted of a mixture of 30 parts by weight of a copolymer of vinylidene chloride and acrylic ester (GEON 660X14) having a T_g of 14°C, and 70 parts by weight of a copolymer of vinyl chloride/acrylic ester (GEON 460X47) having a T_g of 46°C., both copolymers being provided with inherently heat reactive self-cross linking amide functional side groups activated at a temperature of 280°F. Such copolymers are available from the B.F. Goodrich Co. Excess binder and water were removed on the Fourdrinier screen and the glass fiber-binder web was dried in the usual manner on steam heated drying cans. Three different webs having three different basis weights of 55, 62 and 70 lb/3000 sq.ft. were thus prepared.

Fiber blend C was also treated as described above except that the binder consisted of 15 parts by weight of GEON 660x14 and 85 parts of GEON 460X57; the resultant web had a basis weight of 70 lb/3000 sq.ft.

The characteristics of the four webs were as follows:

	Test Procedure	Fiber Blend A	A	B	C
Binder, wt. percent	TAPPI T 413-80	5.5	5.5	5.5	5.4
Basis wt, lb/3000 sq.ft.	TAPPI T 410-79	55	62	70	70
Caliper, in.	TAPPI T 411-76	0.019	0.022	0.025	0.025
Tensile (MD), lb/in.width*	TAPPI T 494-70	8.0	11.0	13.0	9.6
Elongation (MD), percent*	TAPPI T 494-70	1.6	1.6	1.5	1.1
Tensile (CD), lb/in.width*	TAPPI T 494-70	5.5	8.0	10.0	6.8
Elongation (CD), percent*	TAPPI T 494-70	1.9	1.9	2.2	1.4
Gurley Stiffness (MD),mg.	TAPPI T543-84	1800	2600	3400	2967

*at 72°F.

Each sheet was capable of being heated with infra-red to a temperature of 300°F, then rapidly passed while still hot between a pair of polyurethane embossing rolls, thus being subjected to embossing over a rib or boss having a cross section in the form of a segment of a circle with a height of 2mm and a width of 8.5mm without splitting or cracking. Each sheet was also capable of being scored and folded to form pleats from 1 inch to about 9 inches in height, the opposing faces of the pleats being maintained in spaced relation by the embossments at a pleat density of 4-12 pleats per inch. Following the scoring and embossing steps, the temperature of the web was raised to above 280°F to bring about cross linking of the binder, thus increasing the stiffness and form-retaining characteristics of the filter web. The finished pleated and folded filter medium in each case retained its spacing between pleats under a variety of conditions and displayed high air filtration efficiency as shown by the following test results:

	A	B	C	D
Air Resistance, mm H_2O (ASTM F-778-82)	38	38	46	34.5
DOP Penetration,% (ASTM D2986-71)	0.005	0.009	0.001	0.015

In general, the products of the present invention, when embossed and completely cross-linked, display an air resistance (ASTM F-778-82) of 0.5 to 70 mm H_2O and a DOP Penetration (ASTM D2986-71) of 0 to 99%. When the binder content of the product of this invention is below 7%, the filters constructed with proper sealant are capable of passing UL 900, class 1.

CLAIMS

1. A thermoformable filter material comprising:

a glass fibre blend comprising (A) 5 to 35% by weight of chopped strand fibres having average fibre lengths of 3 to 19mm and average fibre diameters of 6 to 20 micrometers, and (B) the balance glass wool having average fibre lengths of 0.1 to 5mm and average fibre diameters of 0.2 to 6 micrometers;

a thermoplastic polymeric binder capable of undergoing cross-linking upon heating to a temperature above 280°F,

the amount of the binder being from 2 to 30% by weight of the total glass fibre blend and binder,

the material having a thickness from 0.012 to 0.040 inches, a tensile strength (MD) from 4 to 25 lb/inch width and a tensile strength (CD) from 2 to 12 lb/inch width, and a basis weight from 40 to 100 lb/3000 sq.ft.

2. A thermoformable filter material as claimed in claim 1 which exhibits an elongation of at least 2.0% without cracking or splitting during embossing at 200°F over a boss having a cross section in the form of a segment of a circle having a height of 2mm and a width of 8.5mm.

3. A thermoformable filter material as claimed in claim 2 which retains a permanent elongation of at least 1.0% within the embossment after cross-linking and cooling to room temperature.

4. A thermoformable filter material as claimed in any

of claims 1 to 3 in which the fibre blend comprises 8 to 15% by weight of the chopped strand fibres, the balance being the glass wool.

5. A thermoformable filter material as claimed in any of claims 1 to 4 wherein the amount of the binder is from 3 to 6% by weight.

6. A thermoformable filter material as claimed in any of claims 1 to 5 which has a basis weight from 55 to 75 lb/3000 sq.ft. width.

7. A thermoformable filter material as claimed in any of claims 1 to 6 which retains a permanent elongation of 1 to 5% within an embossment after cross-linking and cooling.

8. A thermoformable filter material material as claimed in any of claims 1 to 7 wherein the chopped strand fibres have average fibre lengths of 6 to 13mm.

9. A thermoformable filter material as claimed in any of claims 1 to 9 wherein the glass fibre wool has average fibre lenghts of 1 to 3mm.

10. A thermoformable filter material as claimed in any of claims 1 to 9 which has a thickness from 0.012 to 0.030 inches.

11. A thermoformable filter material as claimed in any of claims 1 to 10 which has a Gurley stiffness (MD) of at least 1500mg.

12. A thermoformable filter material as claimed in any of claims 1 to 11 wherein the binder is a vinyl or vinylidene polymer or copolymer.

13. A thermoformable filter material as claimed in any of claims 1 to 12 which is a vinylidene chloride/acrylic ester copolymer.

14. A process for the preparation of a thermoformable filter material, the process comprising admixing:

(A) 5 to 35% by weight of chopped strand fibres having average fibre lengths of 3 to 19mm and average fibre diameters of 6 to 20 micrometers;

(B) the balance of glass wool having average fibre lengths of 0.1 to 5mm and average fibre diameters of 0.2 to 6 micrometers; and

(C) a thermoplastic polymeric binder capable of undergoing cross-linking upon heating to a temperature above 280°F, thereby forming a material having a thickness from 0.012 to 0.040 inches, a tensile strength (MD) from 4 to 25 lb/inch width and a tensile strength (CD) from 2 to 12 lb/inch width, and a basis weight from 40 to 100 lb/3000 sq.ft.

15. A process as claimed in claim 14 wherein the admixing is by wet blending.

16. A process as claimed in claim 14 or 15 wherein the admixing is to form a slurry.

17. A process as claimed in any of claims 14 to 16 wherein the chopped strand fibres and glass wool are first blended to form a glass blend and contacted with

an aqueous dispersion of the binder.

18. A process as claimed in claim 17 additionally comprising drying the glass blend and binder.

19. A process for the preparation of a filter, the process comprising embossing and/or pleating a thermoformable filter material, the material comprising:

a glass fibre blend comprising (A) 5 to 35% by weight of chopped strand fibres having average fibre lengths of 3 to 19 mm and average fibre diameters of 6 to 20 micrometers, and (B) the balance glass wool having average fibre lengths of 0.1 to 5mm and average fibre diameters of 0.2 to 6 micrometers;

a thermoplastic polymeric binder capable of undergoing cross-linking upon heating to a temperature of above 280°F; the amount of the binder being from 2 to 30% by weight of the total glass fibre blend and binder;

the material having a thickness from 0.012 to 0.040 inches, a tensile strength (MD) from 4 to 25 lb/inch width and a tensile strength (CD) from 2 to 12 lb/inch width, and a basis weight from 40 to 100 lb/3000 sq.ft.

20. A process as claimed in claim 19 which is preceded by scoring the material to assist pleating.

21. A process as claimed in claim 19 or 20 additionally comprising embossing the material.

22. A process as claimed in claim 21 wherein the

material is heated up to about 300°F and passed through embossing rolls.

23. A process as claimed in claim 23 wherein the heating is by infra-red radiation.

24. A process as claimed in any of claims 19 to 23 wherein the material is heated to above 280°F to induce cross-linking in the binder.

25. A thermoformable filter material prepared by a process as claimed in any of claims 14 to 18.

26. A filter prepared by a process as claimed in any of claims 19 to 24 and/or comprising a thermoformable filter material as claimed in any of claims 1 to 13.

27. A thermoformable filter material substantially as herein described.

28. A filter substantially as herein described.

29. A process for the preparation of a thermoformable filter material substantially as herein described.

30. A process for the preparation of a filter substantially as herein described.

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